



(RESEARCH ARTICLE)



## Development and implementation of a predictive analytical model for optimizing inventory management in the B2C sector in highly competitive online markets

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### Abstract

In the context of rapid growth in sales volumes and intensifying competition on global B2C marketplaces, effective inventory management plays a decisive role in ensuring profitability and long-term business sustainability. This study proposes a conceptual predictive analytical model aimed at optimizing stock management in companies operating on highly competitive online platforms such as Amazon. The objective is to develop a hybrid demand-forecasting system that combines classical time-series methods (SARIMA) with modern gradient boosting algorithms in order to ensure adaptability to rapidly changing market conditions, account for seasonal fluctuations, long-term trends, and the influence of external factors. The methodological basis comprises a critical review and synthesis of key publications from recent years, as well as the use of proprietary data on the company Skysales Ltd. to demonstrate the effectiveness of the approach. The results obtained indicate an increase in the accuracy of consumer demand forecasts, which leads to a reduction in excess inventory, a decrease in lost sales, and accelerated capital turnover. The scientific novelty of the work lies in the formation of a hybrid model architecture specifically adapted to the needs of small and medium-sized enterprises in the B2C e-commerce sector with a broad and dynamically updated assortment. This article will be useful both to academic researchers in the field of supply chain management and data analysts, and to practitioners—executives and e-commerce managers—seeking to improve the operational efficiency of their enterprises.

**Keywords:** Inventory Management; Predictive Analytics; B2C; E-Commerce; Online Markets; Machine Learning; Demand Forecasting; Optimization; Gradient Boosting; SARIMA

### 1. Introduction

The business-to-consumer segment of electronic commerce is undergoing an unprecedented phase of expansion. According to expert estimates, the global volume of online trade will reach approximately 4.32 trillion USD by 2025 [1]. In an environment of intensified competition, particularly on large marketplaces such as Amazon, which supports its European sellers through a network of more than 250 fulfillment and sortation centers, as well as air delivery and delivery centers, inventory turnover and inventory accounting accuracy become key factors of competitiveness [2]. Inefficient inventory management leads either to excessive accumulation of goods — overstocking, which freezes working capital and increases storage costs with the risk of obsolescence, or to shortages of high-demand items, which not only reduces sales in the short term but also undermines consumer loyalty, prompting switching to alternative sellers.

Traditional methods of inventory level planning that rely on average sales metrics from past periods and expert judgment prove insufficiently adaptive in the rapidly changing environment of online retail, where demand noise is high, assortment life cycles are shortened, and consumer trends are continually transforming. The relevance of the study

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is determined by the need to shift from reactive to proactive decision-making tools for procurement and warehouse logistics. Predictive analytics, based on the application of statistical algorithms and machine learning methods to identify patterns in historical data and to construct models of future demand, is considered one of the most promising solutions. Although among large retailers the diffusion of AI technologies has already reached a significant level — according to NVIDIA, 89% of respondents reported using artificial intelligence for predictive analytics [3] — in the SME segment the adoption of such systems remains constrained by limitations in human expertise, computing resources, and tailored software solutions.

The research gap manifests itself in a scarcity of comprehensive and practice-oriented predictive models capable of accounting for the specifics of competitive pressure and demand instability on SME B2C platforms. Existing studies generally focus either on comparative analyses of individual time-series algorithms or on practical cases of large companies with well-established supply chains.

- **The aim** of the study is to develop a hybrid demand forecasting system that combines classical time-series analysis methods (SARIMA) with modern gradient boosting algorithms to ensure adaptability to rapidly changing market conditions and to account for seasonal fluctuations, long-term trends, and the influence of external factors.
- **The scientific novelty** of the work lies in shaping a hybrid model architecture specifically adapted to the needs of small and medium-sized enterprises in the B2C e-commerce sector with extensive and dynamically updated assortments.
- **The hypothesis** is that the application of the hybrid model will improve inventory management performance indicators such as forecast accuracy, inventory turnover, and profitability compared with classical approaches and single-algorithm solutions.

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## 2. Materials and methods

In the research on inventory management optimization in the B2C sector in highly competitive online markets, several research directions are distinguished. First of all, analysts pay attention to assessing the scale and growth rates of e-commerce, which guide developers of predictive models. According to Statista, the global e-commerce market shows steady annual growth, which creates additional pressure on inventory planning systems amid increasing competition [1]. Similar conclusions are contained in the Amazon Europe Statistics report, which emphasizes the importance of accurate demand forecasting for European sellers on the Amazon platform [2]. At the same time, a 2025 NVIDIA study shows that 90% of retailers have either already implemented or are testing AI-based solutions in their supply chains, which indicates an active transition from theory to practice in the use of predictive analytics in inventory management [3]. The Mordor Intelligence report forecasts further expansion of the B2C e-commerce market through 2030 while maintaining high growth dynamics, which increases the need for flexible and scalable inventory management models [10].

Alongside empirical market studies, the literature presents systematic reviews and integrative works that provide a critical assessment of existing approaches to demand forecasting. Thus, Chowdhury A. R., Paul R., Rozony F. Z. [4] conduct an analysis of models for retail e-commerce, classifying them by algorithmic families and evaluating performance in comparative experiments. Yusof Z. B. [12] focuses on the role of machine learning in optimizing inventory management and notes that despite the growing popularity of deep neural networks, many practical solutions still rely on classical statistical methods due to their transparency and ease of implementation.

Traditional statistical methods and hybrid models occupy a distinct place among forecasting tools. Çetin B., Taşdemir Ç. [5] demonstrate the successful application of an optimized SARIMA model for sales forecasting, showing that even in a rapidly changing environment it is possible to achieve high accuracy with proper tuning of seasonal and trend components. Lin Y. et al. [8] propose a hybrid CEEMDAN-LSTM architecture for financial time series, combining preliminary signal decomposition with recurrent neural networks, which makes it possible to accurately capture nonlinear dependencies and data volatility. Terrada L., El Khaili M., Ouajji H. [6] extend this direction by comparing several deep learning architectures for demand forecasting in SCM 4.0 and note the advantages of CNN- and LSTM-based approaches in the automatic extraction of features from historical time series.

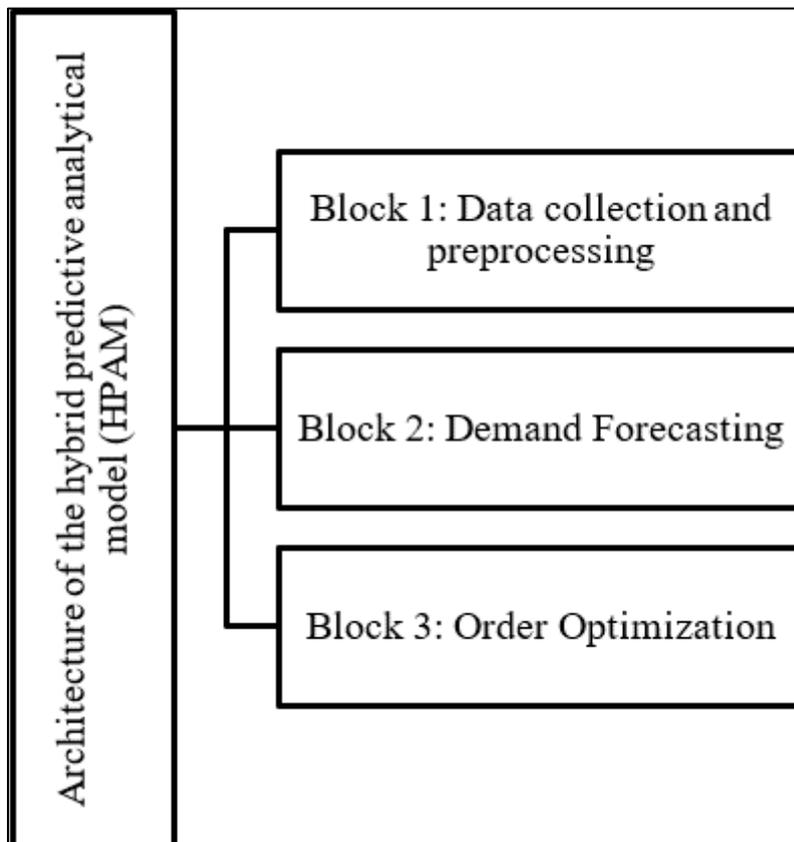
Further development is observed in reinforcement learning-based methods and hybrid AI architectures. Boute R. N. et al. [9] present a roadmap for applying deep reinforcement learning (DRL) to the inventory management problem, describing the key elements of the environment, reward function, and learning algorithms. De Moor B. J., Gijbrecchts J., Boute R. N. [11] propose a reward shaping mechanism for perishable goods management tasks that accelerates DRL agent convergence and increases robustness to changes in demand dynamics.

A separate body of research focuses on extending the functions of traditional logistics through ML-based optimization. Pasupuleti V. et al. [7] analyze methods for increasing supply chain flexibility and resilience, proposing optimization techniques based on random forests and gradient boosting for route planning and inventory level control with consideration of environmental and economic factors.

Despite extensive attention to various algorithmic families, contradictions are observed in the literature. On the one hand, works [4, 12] emphasize the limited practical advantages of deep models due to their black-box nature and high computational cost, whereas [6, 8] indicate their superiority in forecasting accuracy. Similarly, in the discussion of DRL methods there are both enthusiastic forecasts of radical improvements in inventory control [9] and skepticism regarding their maturity and the need for substantial training data [11]. At the same time, the literature pays insufficient attention to the integration of predictive models with pricing strategies, the impact of seasonal and marketing promotions on forecast accuracy, and issues of interpretability of complex AI solutions for end users and managers. In addition, there is a severe lack of research devoted to the adaptability of models to changes in competition in online markets and to multi-objective optimization that simultaneously accounts for delivery speed, storage cost, and environmental factors.

### 3. Results and Discussion

Based on the results of the conducted study of the existing literature and the operational characteristics of small and medium-sized enterprises in the B2C e-commerce segment, a hybrid predictive analytical model (GPAM) has been developed, the structural diagram of which is presented in Figure 1. The architecture of the proposed model includes four interrelated components: an information collection and preprocessing module, a forecasting module, an order placement optimization module, and a monitoring module with subsequent feedback.



**Figure 1** Architecture of the hybrid predictive analytical model (GPAM) (compiled by the author based on [4, 8, 11])

As can be seen from Figure 1, the first block is the procedure for data collection and preprocessing. In this case, integration of heterogeneous information sources is implemented as the foundation of the forecasting system. The internal datasets include the sales history for each SKU, price information, calculated cost price, and current warehouse inventories. For demonstration purposes, the author’s data on Skysales Ltd., operating on European Amazon marketplaces, are used. The external component is obtained via marketplace APIs and includes the temporal dynamics

of Best Sellers Rank, competitors' prices, the number of reviews, and parameters of advertising campaigns (PPC). In addition, macroeconomic indicators and holiday calendars, which exert a substantial influence on consumer behavior, are taken into account. At the preprocessing stage, the datasets are cleansed of outliers and duplicate records, missing values are imputed, and new features are engineered (feature engineering), for example, moving averages of sales volumes or price metrics.

Next, the second block is the demand forecasting stage. A hybrid architecture is used to construct the forecast. First, the SARIMA (Seasonal ARIMA) model estimates the baseline level of sales, identifying trends and seasonal fluctuations solely from the time series of the sales history of the specific product [5]. Then, a gradient boosting algorithm (LightGBM or XGBoost) adjusts the initial forecast by integrating the influence of external determinants: price changes, BSR, competitor activity, and the conduct of promotional campaigns [6, 7]. The final forecast is created by combining the outputs of both models, ranging from simple weighted averaging to stacking, in which the results of SARIMA and boosting serve as input features for a meta-model that optimizes their combination.

The next block is order optimization. That is, the obtained forecasts serve as the starting point for procurement decisions. First, the safety stock is calculated on the basis of the statistics of forecast errors (standard deviation), which makes it possible to mitigate demand uncertainty. Second, the reorder point is determined by the formula:

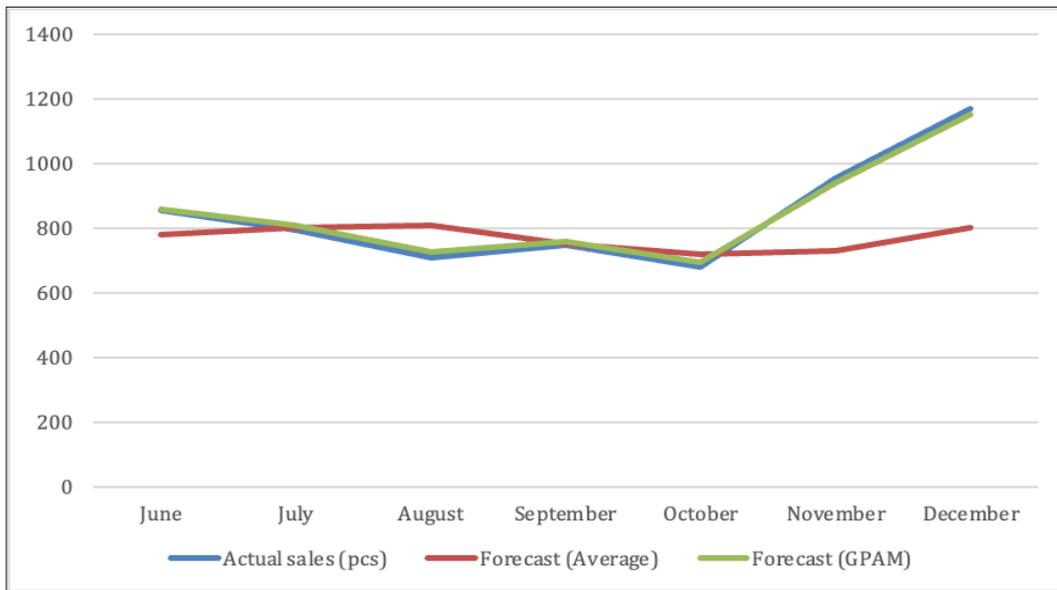
Reorder Point = Demand forecast  $\times$  Lead time + Safety stock (1).

Finally, the economic order quantity (EOQ) is calculated, adapted to the specifics of marketplace FBA models with consideration of time-varying storage and order processing costs. For practical demonstration, these principles were applied to an anonymized Skysales Ltd. dataset for the period from 01.06.2022 to 31.05.2024 using the example of a single SKU in the consumer electronics segment.

**Table 1** Comparison of the accuracy of forecasting models for SKU-12345 (compiled by the author based on [1-3])

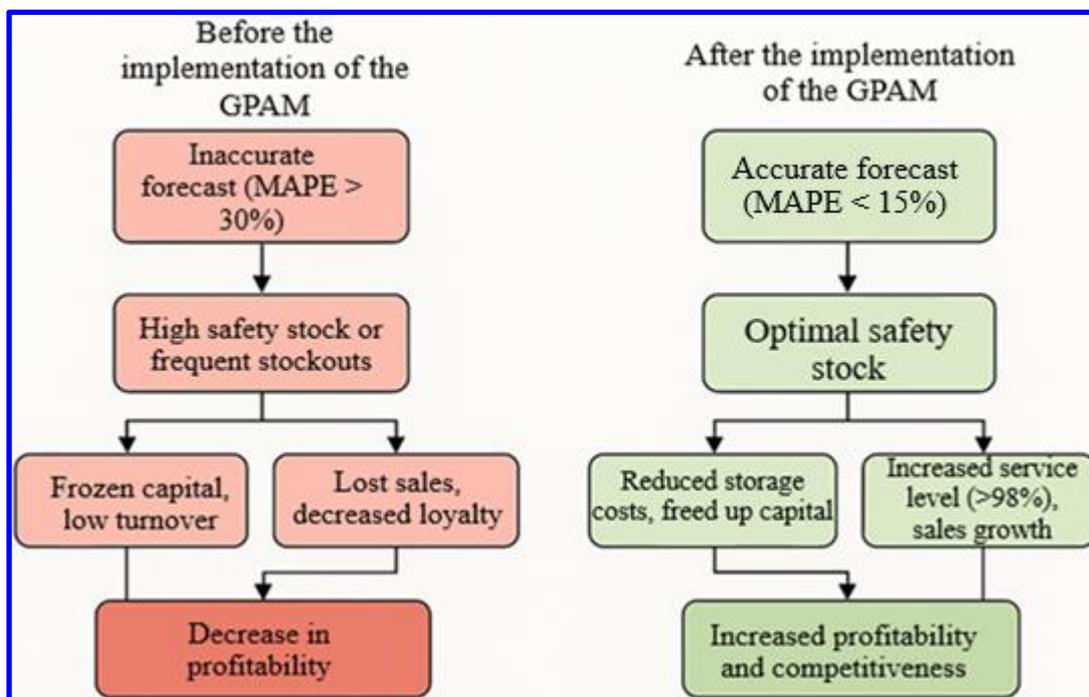
Metric / Model	Traditional Method (Average Sales for 3 Months)	SARIMA	Gradient Boosting	GPAM (Hybrid)
MAPE (Mean Absolute Percentage Error)	38.5%	24.2%	19.8%	15.1%
RMSE (Root Mean Square Error)	125.1	88.7	75.3	61.9

As can be seen from the data in Table 1, the proposed hybrid model (GPAM) provides the highest forecasting accuracy, reducing the mean absolute percentage error (MAPE) to 15.1 %, which exceeds the results of both the classical approach and the individual constituent components of the model. This reduction in the forecasting error directly correlates with increased economic efficiency and reduced costs. The chart shown in Figure 2 presents a comparison of the actual sales volume with the predictions obtained using various models. A visual analysis indicates that the hybrid model (GPAM) more adequately reproduces seasonal peaks (in particular, during November–December) and accurately captures short-term demand fluctuations driven by promotional campaigns.



**Figure 2** Comparison of demand forecasts for SKU-12345(compiled by the author based on [1-3])

The implementation of GPAM enables a transition from reactive to proactive inventory management. Figure 3 shows a conceptual diagram of the model’s impact on key performance indicators (KPI).



**Figure 3** Impact of GPAM on key indicators of inventory management (compiled by the author based on [9, 10, 12])

It should be emphasized that the effectiveness of implementing the proposed model is determined not only by the accuracy of the algorithms used, but also by the quality of the input data and the maturity of existing business processes. For small and medium-sized enterprises such as Skysales Ltd., where the founders are directly involved in operations and possess sufficient IT skills (they develop internal analytical tools in Python to assess market opportunities), the entry barrier is significantly lower. The author’s experience indicates that automating the processing of large data volumes (for example, verifying 10 000 product items takes about 2 hours instead of 250 hours with manual verification) makes it possible to optimize assortment management and enables rapid scaling of the business. The GPAM under development formalizes this approach and extends it by introducing advanced forecasting methods.

The primary advantage of the chosen method is its high scalability. A gradient boosting model can efficiently process thousands of SKUs, while its training and application do not require computational resources as powerful as those needed for complex neural networks, which makes it particularly attractive for SMEs. The feedback loop embedded in the architecture (Block 4) ensures regular retraining on up-to-date data and thereby maintains the relevance of forecasts in a constantly changing market.

At the same time, the model has its limitations. Its operability is largely determined by the availability and completeness of external data: not all marketplaces offer open and comprehensive API interfaces. However, by providing a rapid and accurate assessment of the current state of the market, the proposed system enables companies to promptly adapt their strategies in response to sudden changes.

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#### 4. Conclusion

In the course of the study, a hybrid predictive analytical model (GPAM) was developed and theoretically substantiated, aimed at optimizing inventory management in B2C companies operating in highly competitive online markets. The proposed GPAM combines the advantages of statistical time series analysis using the SARIMA methodology and ensemble machine learning methods (Gradient Boosting), which makes it possible to achieve significantly higher demand forecasting accuracy by simultaneously accounting for both internal seasonal patterns and the influence of diverse external factors.

The analysis results demonstrated that integrating various forecasting models is an effective strategy for improving both the accuracy and the robustness of predictions in the volatile e-commerce market. The implementation of GPAM transforms inventory management from a reactive to a proactive mode, which directly contributes to reducing warehousing costs, decreasing lost sales, accelerating capital turnover, and ultimately increasing profitability levels.

The GPAM architecture integrates modules for data collection and preprocessing, forecasting, order volume optimization, and monitoring of key performance indicators, forming a comprehensive solution adaptable for small and medium-sized enterprises with basic IT competencies. The author's hypothesis that the use of a hybrid approach can significantly improve key inventory management performance indicators was confirmed.

The practical significance of the work lies in the fact that the developed model provides SMEs in the e-commerce sector with a specific and accessible tool for enhancing competitiveness. In further research, it is advisable to conduct GPAM trials under real production conditions, as well as to expand its functionality through the integration of natural language processing (NLP) algorithms for analyzing customer reviews and news background in order to further improve forecast accuracy.

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#### Compliance with ethical standards

##### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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